chapters to microscopic analysis, the deficiencies thus left will be obvious; to those who knew the author personally, and were thus able to estimate the heavy burdens which were laid on him during the anxious years 1914–18, these blemishes will be regarded as veritable war wounds.

Thus, this fourth edition of a recognised standard work, even with its blemishes, will be to workers in the oil world an appropriate memorial to its author. In most chapters there are the results of his characteristically painstaking assembly of data; the constant sense of relativity shown in their summary; the judicial instinct with which conflicting theories are balanced; the conscientious recognition of the work of others; the cautious estimates of "prospects" likely to affect commercial interests; the record of observations privately obtained from innumerable friends; and, finally, the signs of war weariness which probably brought about the fatal illness to which he succumbed only two days after passing for press the complicated section on shale oil and allied industries.

The publication of this edition marks a definite stage in the history of petroleum technology; in complexity its ramifications have now passed beyond the comprehension of any one individual; no single person can hope to prepare the fifth edition of Redwood's "Treatise." Its author has passed away, but his spirit remains incarnated in the Institution of Petroleum Technologists which he founded just before the war, and that body might well regard as its chief mission the maintenance up to date of this its bible as a standard work of reference. The Institution has already in the press a volume summarising recent developments in special branches of the petroleum industry, and this work, supplemented by Mr. Dalton's revised and extended bibliography, will bridge many of the gaps left in the Treatise by Sir Boverton Redwood's unexpectedly sudden death. T. H. Holland.

Entropy as a Tangible Conception.

Entropy as a Tangible Conception: An Elementary Treatise on the Physical Aspects of Heat, Entropy, and Thermal Inertia for Designers, Students, and Engineers, and particularly for Users of Steam and Steam Charts. By Eng. Lt.-Commr. S. G. Wheeler. Pp. 76. (London: Crosby Lockwood and Son, 1921.) 8*s*. 6*d*. net.

OPINIONS will differ as to the merits of the title which Lt.-Commr. Wheeler has chosen for this volume. The extreme relativist, who regards the notion of force derived from our muscular sensations as a relic of animism, will no doubt condemn it. "To-day we have dispossessed the demons, but the *ghost of a muscular pull* still holds the planets in place."[1] On the other hand, the student of either physics or engineering will welcome any suggestion which assists him in understanding the nature of the "ghostly quantity," entropy. "The more shadowy the conception to be visualised, the greater the need of a definite material analogy." The quotation is from the instructive presidential address to the Physical Society of London delivered by Prof. Callendar in 1911. Here it is pointed out that the caloric theory is perfectly consistent with Carnot's principle and with the mechanical theory for all reversible processes. The quantity measured in an ordinary calorimetric experiment is the motive power or energy of the caloric, and not the caloric itself. Prof. Callendar identifies caloric with the "thermodynamic function" of Rankine, or the "entropy" of Clausius.

With this address and with the important paper by Sir J. Larmor "On the Nature of Heat" (Proc. Roy. Soc. vol. 94, p. 326, 1918) we imagine Lt.-Commr. Wheeler is not acquainted. He sets out to give a more tangible interpretation of entropy than that afforded by Boltzmann's statement that it is "the logarithm of the probability of a complexion." This he endeavours to do, and in our opinion with considerable success, by means of mechanical analogies. There is, needless to say, nothing novel in such an attempt. Poynting and Thomson, in their text-book on "Heat," direct attention to quantities which are analogous to entropy; indeed, we may, according to Prof. Callendar, go back to "the old picturesque phraseology of the material fluid, implied in Carnot's waterfall." Just as gravitational energy may be regarded as the product of mass and the height of the mass above zero level, so heat energy may be regarded as the product of "thermal inertia" and temperature. Thus entropy, being, as Swinburne called it, "the measure of the incurred waste," may be interpreted as "incurred thermal inertia." But in this book a distinct point, which we had not previously met with in print, is made by considering, not linear, but rotational, motion, so that thermal inertia corresponds to the moment of inertia, mk^2, of a rotating system. Here we have a case where the rotational inertia is capable of variation through changes in the value of k, the radius of gyration.

This may be illustrated by suspending a flat, circular disc from a point in its circumference by a thin wire by means of which it can be spun round around a vertical axis (Fig. 1). At first the disc will rotate about its original vertical diameter, but on the attainment of a certain speed the disc will start to rise, the wire now making an angle with the vertical whilst the disc rotates about an axis through its centre and perpendicular to its plane, the centre remaining vertically below the fixed point of suspension. At a still higher speed the disc will begin to whirl about the point of suspension with the wire and its own plane both practically horizontal. "The changes in inertia of the rotating disc occur at definite speeds as it receives energy, and it is not so improbable as at first sight it may seem, therefore, that the changes in form which occur at perfectly definite temperatures (as, for instance, when heat is added to ice to turn it to water, and to water to turn it to steam) may really take place in a similar manner by some corresponding change in disposition in the particular internal or ionic movement which we imagine to constitute heat; in other words, that this motion may enjoy some form of increased freedom which may be regarded as an increase of thermal inertia."

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[1] Dr. Mott-Smith, in J. M. Bird's "Relativity and Gravitation." (Methuen, 1921.)

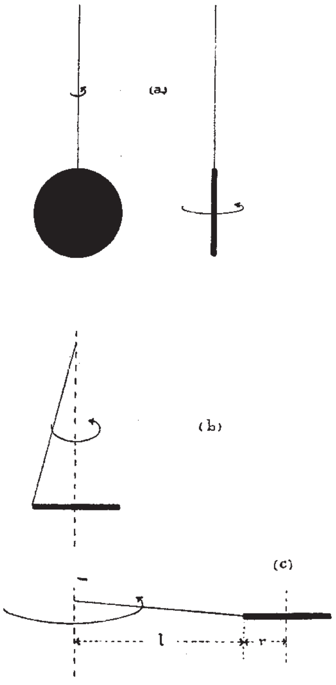

FIG. 1.—An instance of change in rotational inertia.

The conception of entropy as incurred thermal inertia is worked out in detail in the later chapters, and an interesting mechanism is described which affords a parallel to the behaviour of the working substance in an engine (Fig. 2). In this model the actual working substance is represented by an arrangement consisting of a short shaft carrying a pair of heavy "governor" balls mounted on bell-crank levers controlled by varying tension springs. Changes in the rotational inertia of the revolving masses represent changes in the thermal inertia of the working substance. With the apparatus illustrated in the book it is possible to go through a cycle of operations, such as the usual steam-engine cycle (Rankine's cycle) or Carnot's cycle, and examine the analogies between thermal and mechanical processes in detail. Teachers and students of thermodynamics would be well advised to study this volume.

In connection with such mechanical analogies our attention has been directed to an address delivered before the Institution of Civil Engineers in 1883 by Prof. Osborne Reynolds. The lecturer referred to the work of Rankine, who assumed the thermal motion to be rotatory, and, when compelled to abandon the theory of "molecular vortices," called on all those who taught the subject of thermodynamics to try to find some popular means of illustrating the second law. "The call was made twenty years ago; but I believe up to the present no such illustration has been forthcoming." "The communication of heat to matter means the communication of internal agitation—mob agitation. If, then, we are to make a machine to act the part of hot matter, we must make a machine to perform its work in virtue of internal promiscuous motion amongst its parts." As an illustration, Osborne Reynolds instances the possibility of raising a bucket by violently shaking the upper end of a heavy rope or chain. A modification of the illustration is afforded by a kind of chain composed of a series of parallel horizontal bars of wood connected and suspended by two strings. "By giving a circular oscillation to the upper bar, the whole apparatus is set into a twisting motion (agitation); the strings are continually bent, and the vertical length of the whole system is shortened." Osborne Reynolds refers also to the governor of a steam-engine, which acts by kinetic elasticity depending on the speed. "The motion of the governor is not of the form of promiscuous agitation, but, though systematic, all the motion is at right angles to the direction of operation, so that the principle of its action is the same." Here we have the germ of the model discussed in the book under review. We may venture the opinion that the development of this model owes not a little to the late Prof. A. M.

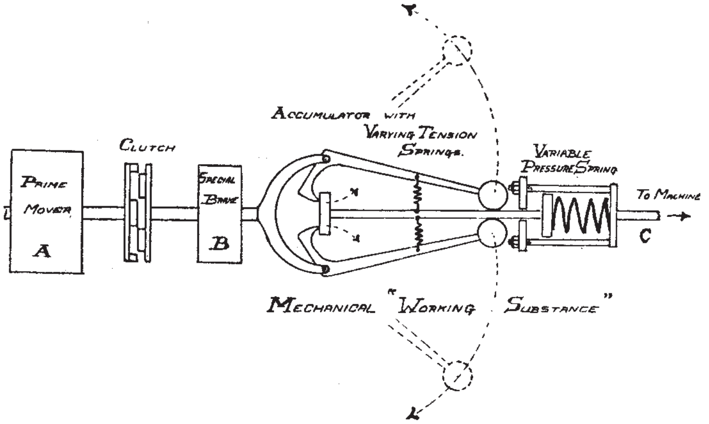
Accumulator with Varying Tension Springs.
Clutch
Prime Mover
A
Special Brake
B
Variable Pressure Spring
To Machine
C
Mechanical "Working Substance"

FIG. 2.—Mechanism illustrating the behaviour of the working substance in an engine.

Worthington, whose name, however, is nowhere mentioned. "These kinetic examples of the action of heat must not be expected to simplify the theory, except in so far as they give the mind something definite to grasp; what they do is to substitute something we can see for what we can barely conceive."

The Mass Formula of Cathode-ray Corpuscles.

Vérification expérimentale de la formule de Lorentz-Einstein. Par Prof. Ch.-Eug. Guye, en collaboration successive avec S. Ratnowsky et Ch. Lavanchy. (Mémoires de la Société de Physique et d'Histoire naturelle de Genève, vol. 39, fasc. 6.) Pp. 273–364 + plates 4–6. (Genève: Muséum d'Histoire naturelle, 1921.) 20 francs.

THIS memoir gives a detailed account of experiments made by MM. Guye and Ratnowsky in 1907–9, and by MM. Guye and Lavanchy in 1911–13, with the object of testing the mass-formulæ of Abraham and of Lorentz for the cathode-ray corpuscles. Preliminary notices of these researches have appeared from time to time, but now they are published in their final form, preceded by a theoretical and historical introduction of twenty pages, whilst twenty pages are devoted to the experiments of Guye and Ratnowsky, and forty pages to those of Guye and Lavanchy; the whole concludes with a small collection of tables and plates. There are records of twenty-seven experiments by Guye and Ratnowsky for the range from $\beta = 0{\cdot}21$ to $\beta = 0{\cdot}59$, and of 151 experiments by Guye and Lavanchy from $\beta = 0{\cdot}25$ to $\beta = 0{\cdot}49$. The first series of experiments gives for the excess of the observed mass of the electron above the Lorentz mass a mean value of five thousandths, and for that above the Abraham mass a mean value of nineteen thousandths, with a probable error of about three thousandths; the second gives for the same quantities two ten-thousandths, eleven thousandths, and one two-thousandth respectively. Thus the evidence of these investigations is strongly in favour of the Lorentz mass formula, in complete agreement with previous researches of similar rank, such as those of Bucherer, Wolz, and Neumann on β-rays, and of Hupka on accelerated photo-electrons.

Like Hupka, Guye and his associates used a relative method; the electric or magnetic force, as the case happened to be, which was required in order to produce a prescribed deflection of a given fast cathode-ray pencil, was compared with that needed to produce an equal deflection of a slow cathode-ray pencil selected as a standard. But whilst Hupka used only the magnetic deflection and relied for the determination of the speed of his photo-electrons on the measurement of the vacuum tube potential employed in accelerating them, Guye and his associates used both the electrostatic and magnetic deflections, not simultaneously, as had been the usual previous practice, but separately and alternately. Thus they eliminated errors due to variations in the state of the vacuum tube, rejecting *ab initio* all experiments in which sudden changes in its condition were suspected. They avoided the large errors which are almost inseparable from the measurement of very high potentials (of the order of 80,000 volts), which completely vitiated Hupka's results, at any rate according to Heil's criticism of his experiments.

The relative method, or method of "identical trajectories," as Guye and his associates call it, has the advantage of not requiring an exact knowledge of the distribution of the electric and magnetic forces, which, especially for the electric field, is very difficult to determine with sufficient accuracy. Since the speed of an electron is not altered by a magnetic field, we can for two cathode-ray pencils of different speeds make the terminal deflections equal by a proper choice of the ratio of the magnetic forces at corresponding points, and so ensure that the trajectories are identical throughout; then the electro-magnetic momenta (transverse mass × speed) will be in the ratio of the magnetic forces—*i.e.* of the electric currents generating the field. But for the electric field the equality of the terminal deflections of two cathode-ray pencils of widely different speeds does not guarantee the identity of their trajectories, if only because the electric field generally alters the speed. In the experiments of Guye and his associates the changes of speed produced amounted to only a few thousandths of the whole, so that the trajectories were very nearly identical, and the error arising from this cause was negligible. Consequently for two cathode-ray pencils of widely different speeds undergoing equal electrostatic deflections the products of their transverse masses into the squares of their speeds could be taken to be in the ratio of the deflecting electric forces—*i.e.* of the differences of the potential between the plates of the condenser used to produce the deflection. Thus the ratios of the speeds and of the transverse masses of the two cathode-ray pencils could be expressed in terms of the measured ratios of the currents in the magnetising coils and the potential differences of the condenser. In this way the speeds and masses of a number of cathode-ray pencils of various high speeds were compared with those of a pencil of a standard low speed, without the need of finding the distribution of the electric or magnetic fields or the discharge potentials for the high-speed pencils.